MATERIALS BUREAU

TECHNICAL REPORT 88-8

LABORATORY TESTING OF CLASS F EARLY STRENGTH CONCRETE

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NEW YORK STATE DEPARTMENT OF TRANSPORTATION

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LABORATORY TESTING OF CLASS F EARLY STRENGTH CONCRETE

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ABSTRACT

The purpose of this study was to determine if variations of NYSDOT Standard Class F mix would result in accelerated strength gain. Type II Portland Cement was used, and the variations were an increased W/C ratio, hot water and insulated curing boxes. The hot water raised the concrete temperature at time of discharge from the mixer.

The Class F mix is used for high early strength gain for pavements and structural slabs, but the standard specifications require a minimum curing period of three days. However, raising the initial concrete temperature, and/or using insulated boards during the curing period, will result in a rapid strength gain. This leads to a shorter required curing period (the time required from placement until traffic would be allowed on the repair). This study showed that by using one or both of these measures, the required curing period is reduced to less than 24 hours.

BACKGROUND

In New York State, high early strength concrete has been available for many years. Due to dense traffic and high maintenance and protection of traffic costs, it has become widely used in the repair and reconstruction of bridge decks and pavements in recent years. A major concern when closing lanes to traffic is how long they will be closed.

Since 1981, downstate areas have utilized calcium chloride accelerated concrete (using Type III Portland Cement) and Rapid Setting Concrete (RSC) repair materials for PCC pavement repairs. Calcium chloride accelerated concrete is used for repairing large areas where lanes can not be closed to traffic for any extended period of time. Traffic lanes are typically opened four hours after placement. Since this work is usually done at night, there is a substantial increase in costs. Type III cement and calcium chloride also add to the increased costs. RSC repair materials are typically used for smaller patches where it is convenient to mix small amounts at a time. For large placements, the cost of RSC repair materials eliminates them as alternatives to calcium chloride accelerated concrete.

Calculations show the minimum compressive strength of concrete needed to resist the bearing stress of the load transfer dowels is 2000 psi. Once this strength is reached, the pavement can be opened to traffic. Thus, 2000 psi has been used as the criterion for determining when traffic will be allowed back on an area repaired with either calcium chloride accelerated concrete or an RSC repair material.

The intent of this investigation was to determine an inexpensive repair (as opposed to the other choices) of PCC pavements which would allow traffic loadings in a relatively short period of time (approximately one day). Although this time period is probably too long for most downstate areas, due to dense traffic, there are many other areas where a lane closure of one day is acceptable.

The Class F mix was chosen because of its high cement content, and under normal curing conditions, traffic is allowed on the pavement after three days.

MATERIAL PROPERTIES

Class F mix has the following proportions:

Cement - 716 lbs/cy

Sand, as % of total aggregate - 34.6%

W/C - 0.38

Air Content Range - 5-9%

Slump Range - 2-3 inches

Coarse Aggregate Gradation - CA2 (3/4" nominal size)

TESTING

Testing consisted of casting eight 6" x 12" cylinders from each of the four batches. All batches had a W/C = 0.40 instead of the 0.38 specified. This was due to problems in obtaining a workable mix, and is closer to what is actually obtained in the field.

In two batches, hot water was used to raise the initial concrete temperature and thus increase the rate of hydration, which is similar to a calcium chloride accelerated concrete mix. The initial concrete temperature, slump, air content and curing method are listed in Table 1.

Table 1 - Characteristics of Class F Mix Used in Strength Gain Study

Batch	Initial Concrete Temperature	Slump	Air Content	Curing Method
1	90°F	1-3/4 in.	5.6%	Insulated (1)
2	91°F	2 in.	6.4%	Capped (2)
3	70°F	2 in.	7.5%	Capped
4	70°F	2-1/2 in.	8.0%	Insulated

(1) Plastic cylinder molds were covered with plastic bags and placed in insulated boxes until time of test.

(2) Plastic cylinder molds were covered with plastic caps and left to cure at room temperature (70°F) until time of test.

A thermocouple wire was inserted into one cylinder from each batch. A temperature potentiometer was used to record the temperature at the time of each compressive strength test. The cylinders containing the wire were the last ones to be tested from each batch.

Compressive testing was done at 6, 24, 48 and 72 hour intervals. Two cylinders from each batch were tested at each time interval. Figure 1 is the compressive strength versus time curve. The higher the initial concrete temperature of the mix, the higher the six hour strength. However, the cylinders which were insulated during curing show a higher one day strength. This is because hydration was occurring at a much faster rate in the insulated cylinders than the capped cylinders. This is shown in Table 2 by the higher temperatures of the insulated cylinders, in which the heat, a by-product of hydration, is being evolved at a much faster rate.

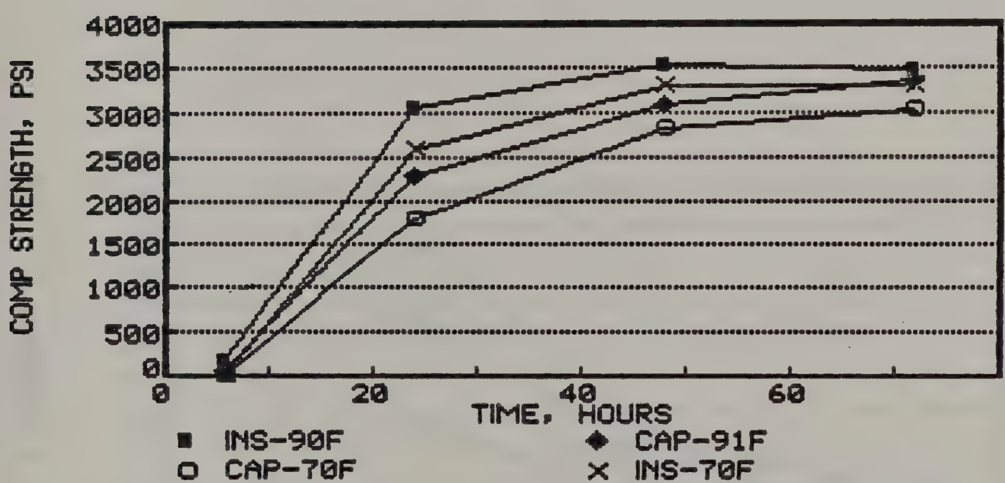

Figure 1 - Strength Curve For Cylinders Used in Study*

* Compressive strength values between the actual test values are conservative due to the straight lines used to connect the actual test values.

Table 2 - Temperature of Cylinders at Time of Test, °F

	Testing Time			
Batch	6 hr.	24 hr.	48 hr.	72 hr.
1	103.0	136.0	107.0	90.0
2	86.0	72.0	70.0	68.0
3	72.0	73.5	70.5	70.0
4	77.0	131.5	107.0	90.5

In a large mass of concrete, such as a slab, a large rise in the temperature results. By retaining the heat of hydration, concrete undergoes autogenous curing, which increases the rate of hydration and results in a higher early strength. Although concrete acts as an insulator because of its low conductivity, covering it with insulation boards prevents large temperature gradients throughout. This increases the rate of hydration, and minimizes shrinkage cracks.

Figure 2 shows the effects of initial concrete temperature and insulated curing on compressive strength. Only percentages from 24 hours on were given because of the low six hour strengths. The chart shows that the faster the heat gain, the higher the compressive strength. As time goes on and the majority of hydration has occurred, the heat dissipates and the insulated curing and high initial concrete temperature have very little effect on the compressive strength.

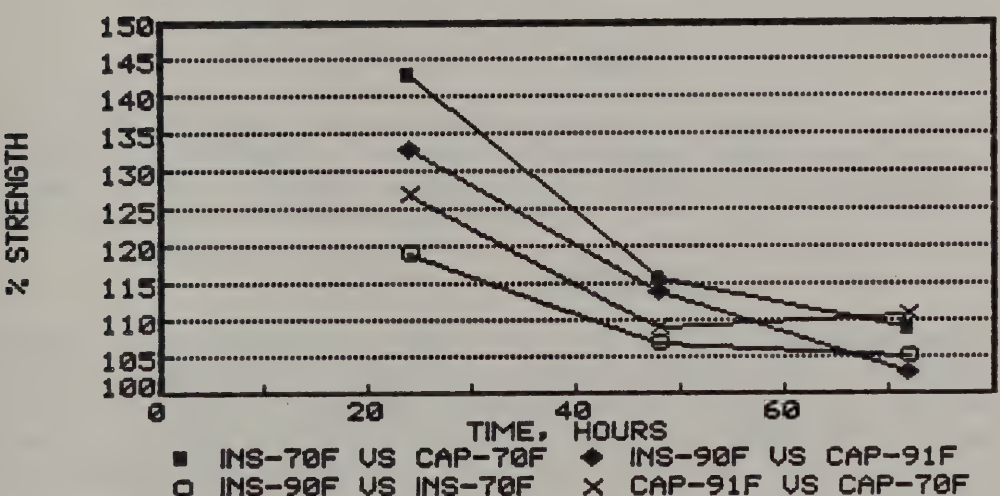

Figure 2

Figure 3 shows the relationship between the insulated cylinders with a 90°F initial concrete temperature and the capped cylinders with a 70°F initial concrete temperature. This chart indicates that the largest early strength gain was realized when both hot water and insulated boxes were used. At twenty-four hours, the cylinders which were cast with an initial concrete temperature of 90°F and cured in insulated boxes had more than one and a half times the compressive strength of cylinders which were cast with an initial concrete temperature of 70°F and cured at room temperature.

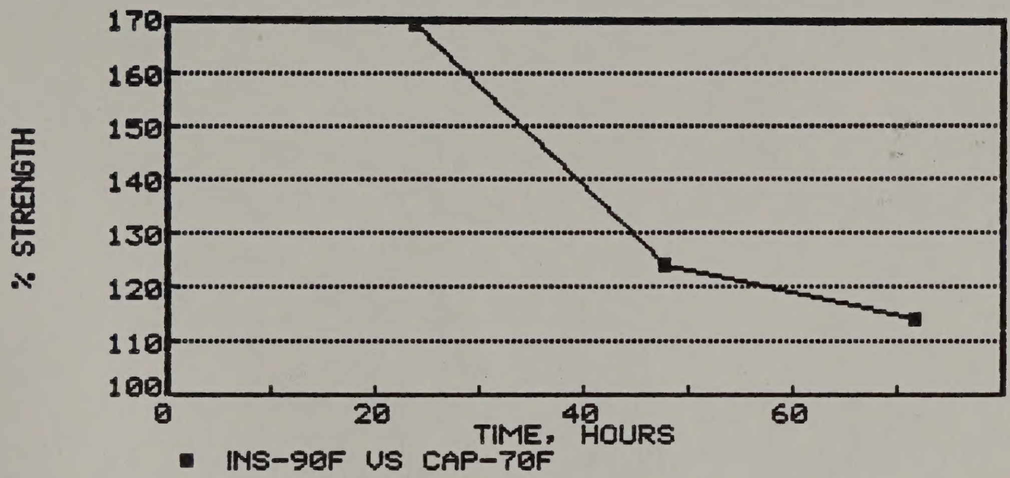

Figure 3

COST

The insulation board will add approximately two percent to the price per cubic yard of Class F, full-depth, in-place. Hot water may result in a minimal price increase. However, these measures will reduce the maintenance and protection of traffic costs and increase user safety.

CONCLUSIONS

A standard Class F concrete mix with only minor variations can be used to obtain sufficient strength to withstand traffic loadings after a 24 hour curing period. Raising the initial concrete temperature and covering repaired areas with insulation boards are two inexpensive measures which can be used to achieve the rapid strength gain needed.

FUTURE PLANS

A special specification has been developed for use of a Class F mix when a one day opening is needed. The ambient air temperature determines what variations to make to the standard procedures. The Materials Bureau will monitor use of the special specification on an upcoming contract in Region 6 and plans to cast cylinders and cure them under the same conditions as the repaired areas on this job.

The effect of curing temperatures below 70°F will be determined from the field trials and additional lab work.